THE TEMPERATURE OF THE HUMAN SKIN

By F. G. Benedict, W. R. Miles, and Alice Johnson

Nutrition Laboratory, Carnegie Institution of Washington, Boston, Massachusetts

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The clinical importance of records of body-temperature, as taken usually in the mouth and occasionally in the axilla or rectum, has quite obscured the physiological significance of the skin temperature. Extensive researches have shown that the temperature of the human body, deep in the body trunk or in any of the natural cavities, remains reasonably constant, although there is a diurnal ryhthm, with a minimum value at about 4 a.m. and a maximum at about 5 p.m. Simultaneous observations of temperature at different parts of the body show that there is almost always a parallelism in curves for temperature. Thus, the temperatures in the rectum or vagina, the well-closed groin or axilla, and the mouth, show similarly shaped curves, although at markedly different levels.

The technical difficulties in recording skin temperature have undoubtedly retarded extensive study in this phase of body-temperature research. The temperature of the human skin is the resultant of several factors, as heat is supplied from the subcutaneous tissues and lost from the surface of the body by radiation, conduction, and the vaporization of water. An attempt to secure accurate records of skin temperature by the application of an ordinary mercury thermometer is obviously useless, for but a small proportion of the bulb of such a thermometer comes in actual contact with the skin. Even thermometers constructed with a special bulb providing a large surface to apply to the skin have a like surface exposed to the environmental temperature. If, as is occasionally done, this outer surface is covered with non-conductive material, there is almost immediately a disturbance in the temperature of the skin due to the fact that there is a retardation of the normal loss of heat, with a consequent accumulation of heat from the subcutaneous tissue. The true temperature of the skin should therefore be recorded by an apparatus which is nearly instantaneous in action and sufficiently protected from the environment to insure a true record of the surface temperature, and not a resultant of skin and environmental temperature.

A method recently used at the Nutrition Laboratory consists of two copper-constantan junctions, one located in a constant-temperature bath—a Dewar flask—and the other applied to the skin. The resulting current which can be measured on any one of several types of galvanometers is directly proportional to the temperature difference between the two junctions. All thermometric lag is thereby eliminated and it is only necessary that the junction which is applied to the body should be properly protected from the environmental temperature. It was found that when this junction was backed with

a light tuft of cotton batting and installed rigidly in a piece of hard rubber, it was possible to apply it to the body and have it assume the surface temperature inside of a few seconds. Thus the period of application was so short that the protecting material did not sensibly affect radiation, conduction, or the vaporization of water.

In our ordinary skin temperature measurements, the junction in the constant temperature bath is kept at 31° or 32°C. When the other junction is exposed to usual room temperature, there is a large deflection of the galvanometer. On applying the junction to the surface of the skin, the amplitude of deflection decreases rapidly and with negative acceleration. The deflection level is reached in about six seconds after application of the junction. Thereafter the rate of movement of the galvanometer is extremely slow, being but a millimeter or two for each successive minute. The explanation of this is that the junction almost instantly assumes the true skin temperature. Thereafter the skin temperature gradually rises, as the protection of the junction with cotton batting and hard rubber stops the loss of heat by radiation, conduction, and vaporization of water, and there is then a 'building up' of the temperature due to the subcutaneous source of heat. As a matter of fact, observations taken for some time show that this rising temperature continues, the length of time depending in large part upon the amount of hard rubber and cotton batting used. For all of our work we have assumed that under these conditions the true skin temperature is obtained at the end of about six seconds after application of the junction.

In connection with an extended series of metabolism experiments on the influence of temperature environment upon the metabolism, it was found that the subject used (a professional artist's model) could withstand exposure to temperatures as low as 14°C. for several hours without shivering. These conditions presented unusual opportunities for studies of skin temperature which would give evidence first, as to the rapidity of the change on exposure of the body to the environmental temperature, and finally as to the absolute level which the skin temperature reaches after prolonged exposure to an environment varying from 14° to approximately 30°C.

When the subject arrived at the Laboratory, the clothing was loosened and temperature measurements were made at numerous points on the skin under the clothing. Prior to these records, the subject clothed and wearing a heavy coat had been exposed to an external temperature of about 17°C. The results of one series of measurements are recorded in table 1. The extreme range in the skin temperature on this particular day was 6.6°C. Special attention is called to the relatively high value of 31.6°C. on the exposed forehead, the record of approximately 34°C. at the waist, a part well protected by clothing, and values of 30°C. or below on the buttocks, shin, and calf. This series is typical of the skin temperature of a normally-clothed woman.

The method of using isolated points, such as those given in table 1, can be much improved upon by taking advantage of the fact that the thermal junction, when not excessively protected by the cotton batting and hard rubber, almost instantaneously assumes the skin temperature. This is particularly the case if the junction is moved from one part of the skin to another after the hard rubber and cotton have assumed approximately the temperature of the skin. When recording the values of isolated points, we have employed a good grade, direct reading galvanometer, thus making the apparatus compact and portable. The response of the thermal junction is so rapid, however, that when connected with a sensitive aperiodic instrument, i.e., a string galvanometer, it is perfectly possible to move the junction at a moderately rapid rate over the surface of the body and record photographically a continuous and true temperature curve for an infinite number of points on the skin.

TABLE 1

RECORDS OF SKIN TEMPERATURE UNDER THE CLOTHING

MEDIAN LINE		RIGHT SIDE		LEFT SIDE	
Location	°C.	Location	°C.	Location	°C.
Front		*Front*		*Front*	
Forehead	31.6	Neck	32.5	Neck	32.1
Second rib	30.3	Nipple line		Nipple line	
Fourth rib	32.1	Upper chest	33.6	Upper chest	33.7
Lower edge breast bone	33.2	Under breast	33.8	Under breast	33.7
7.0 cm. above umbilicus	34.4	Waist	34.4	Waist	34.7
3.0 cm. below umbilicus	33.4	Groin	34.0	Groin	32.8
11.5 cm. below umbilicus	31.8	Thigh	30.7	Thigh	31.1
		Shin	29.8	Shin	30.9
		Back		*Back*	
		Shoulder blade (above)	33.6	Shoulder blade (above)	33.7
		Shoulder blade (below)	32.5	Waist	33.7
		Waist	33.7	Buttock	29.9
		Buttock	30.5	Thigh	31.4
		Thigh	31.0	Calf	28.2
		Calf	28.1	Hand	32.3
		Hand	32.5		

To illustrate our many results obtained by this latter method, two typical curves are given in figure 1. These were obtained after the nude subject had been exposed to an environmental temperature of 14.6°C. for two and one-half hours, the greater part of the time in the standing position. The upper curve follows the left mammillary line, while the lower curve was taken in a corresponding position on the back. An extraordinary difference in skin temperature at the different points may be noted, the extreme range on the front and back showing differences of 10°C. or more. The rectal temperature taken simultaneously was 36.7°C.

The pronounced influence of the environmental temperature upon the curve for the skin temperature was especially studied by making temperature photographs over exactly the same line at intervals from the moment of disrobing

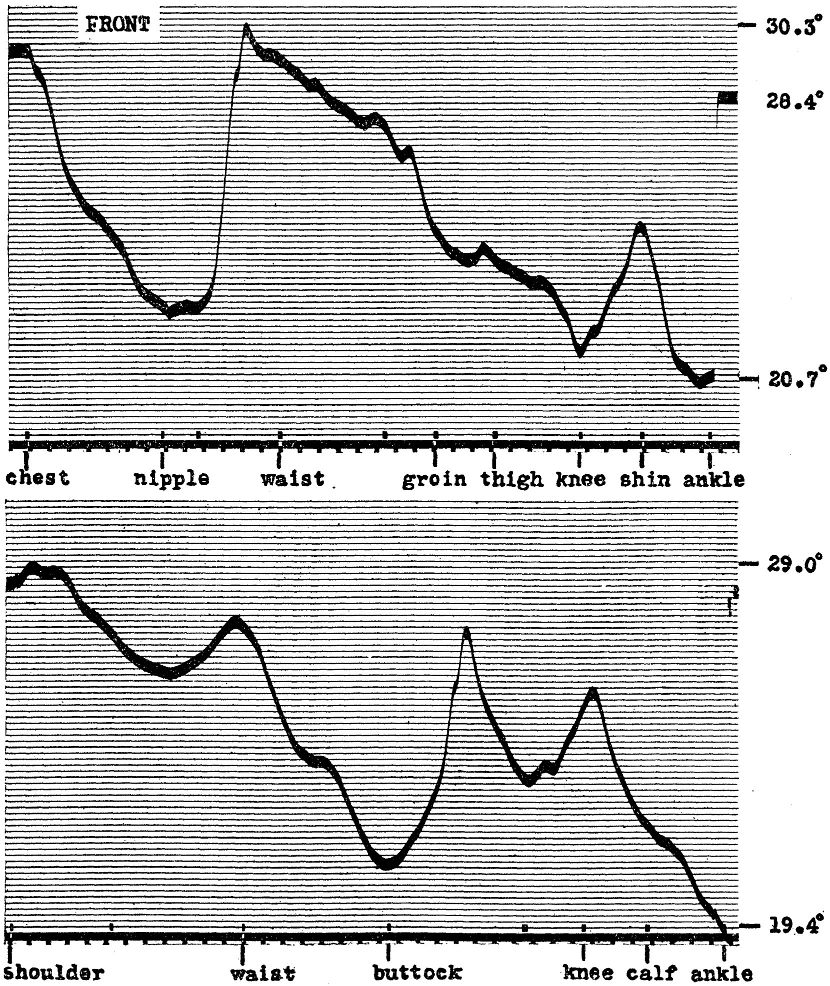

FIG. 1

Photographic records from a string galvanometer for skin temperatures at different parts of the nude body following a $2\frac{1}{2}$ hour exposure to an environmental temperature of 14.6°C. The thermal junction was moved at constant tempo from shoulder to ankle. Time registered at bottom of each curve is in 2-second intervals.

to the end of the period of prolonged exposure to cold. As would be expected, these show a progressive increase in the amplitude of the curve as the time of exposure is prolonged; marked changes occurring even inside of the first fif-

teen minutes. Similar studies made at the end of the exposure to environmental temperatures varying from 14° to 30°C. show a distinct tendency towards a flattening out of the curves at the higher temperatures. Thus when the thermal junction was passed down the front and back of the body over exactly the same lines and at the end of two and one-half hours' exposure, the difference between the highest and lowest points in the curves was 10.6°C. with an environmental temperature of 14.6°C.; 9.8°C. with a temperature of 19°C.; 5.4°C. with a temperature of 25.8°C.; and 4.2°C. with a temperature of 30°C.

This study of the temperature of the skin has two important bearings upon all investigations on the heat production of the human body. First, in all researches on direct calorimetry it has been necessary to corrct the heat actually measured by the calorimeter for the heat gained or lost from the body as the result of changes in temperature. Heretofore it has been assumed that as temperature curves measured either deep in the body trunk or in the artificial cavities are similar, a change of 0.1° in rectal temperature indicates a change of 0.1° in the temperature of the entire body. Our observations, particularly with cold temperature environments, show skin temperatures falling several degrees even when interior body-trunk temperatures may be simultaneously rising slightly. The correction of direct heat measurements by records of the rectal temperature is thus open to grave criticism. Unfortunately no substitute correction can as yet be offered. Secondly, these pronounced differences in skin temperature have great significance in any consideration of the so-called 'law of surface area.' It is still maintained by many physiologists that, practically independent of species, the heat production of the quiet organism is determined by its surface area. Our observations show clearly that, contrary to popular impression, the temperature of the skin, presumably one of the most important factors affecting heat loss, is very far from uniform for we have seen that even with well-clothed individuals differences in the temperature of various localities of 4° to 5°C. are of regular occurrence. These observations bring to light and establish one more serious objection to the legality of the conceptions underlying the 'body-surface law.'

ON A CERTAIN CLASS OF RATIONAL RULED SURFACES

By Arnold Emch

Department of Mathematics: University of Illinois

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As is well known, ruled surfaces, or scrolls as Cayley calls them, may be generated or defined in a number of ways. There exists, for example, a one-to-one correspondence between ruled surfaces and a certain class of partial differential equations, so that the theories of the two classes are abstractly identical.